

U. S. DEPARTMENT OF COMMERCE

BUREAU OF FISHERIES

Fishery Circular No. 12

Issued August, 1932

INTRODUCTION OF JAPANESE OYSTERS INTO THE UNITED STATES¹

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INTRODUCTION

The apparent progress in the cultivation of the Japanese oyster in the State of Washington and the attempts to introduce this species into the waters of Oregon, California, and even of the Atlantic coast bring before the American oyster industry a new problem, which, besides its economic aspect, is of great importance from the point of view of conservation of our native species and maintenance of the high standard of our natural sea food products.

Although the importation of new edible mollusks into the waters which heretofore were not used for cultivation of shellfish or were unsuitable for raising native forms may be desirable, the bringing of a foreign species into the territory already used for the cultivation of a native mollusk may be detrimental to the industry. It is, therefore, the purpose of this paper to call attention of the oystermen to the dangers of importing Japanese oysters into waters of the Atlantic coast and Gulf of Mexico where the propagation of the native American oyster may suffer from competition with this oriental species.

An introduction of any new species is certain to exert considerable influence on the life of the native animals and plants among which the newcomer is placed. By taking space previously occupied by

¹ Approved for publication, May 2, 1932.

others and by using the available food, the immigrant upsets the balance which had existed, and, therefore, intensifies the struggle for existence among the various members of the community. If it propagates successfully and rapidly increases in number, some of the older members of the community must give their place and share of food. The ecological problems involved in this process are more complex than they appear to be at first glance. No organism exists that is free of parasites or other forms which use its body as a place of abode. Some of them being harmless to their host may in a new environment become dangerous enemies of useful animals and plants. The history of man's struggle with injurious insects gives numerous instances of damage and devastation caused by such undesirable immigrants, as for instance the corn borer, Mediterranean fruit fly, gypsy moth, and others too numerous to be listed here.

Introduction of fresh water or marine forms, being for obvious reasons more difficult than bringing in plants or insects, became possible only after the development of modern means of transportation. Many of these forms protected with shells do not suffer from a long exposure to air and can, therefore, withstand transportation over long distances. Thus, experience of oyster growers of this country and abroad shows that edible oysters can be shipped across this continent and to Europe and, if the temperature is not high, survive the voyage very well. Four years ago several bushels of American oysters were shipped from Chesapeake Bay to Honolulu. The oysters survived the trip without great mortality and are still living in one of the bays of Oahu Island. Australian oysters shipped from Melbourne to the Hawaiian Islands arrived in good condition and established themselves near Honolulu. Although several foreign fishes and mollusks were introduced into our waters, the oyster is the only organism the importation of which is carried out on a large commercial scale.

Accurate prediction of what may happen when a large number of specimens of foreign mollusks are introduced into a body of water is a difficult and highly speculative undertaking. An attempt to foresee the effects of such an introduction can be made, however, on the basis of previous experience coupled with the knowledge of the life history and requirements of that particular organism. We shall, therefore, describe first the natural habitat and life history of the Japanese oyster, which will be the main subject of our discussion.

THE COMMON JAPANESE OYSTER

DESCRIPTION

There are in Japanese waters at least 19 species of oysters, 5 of which are considered of commercial value. The others are either too small or too sparsely distributed to be of any importance. The oyster, called "Magaki" in Japan, commonly cultivated on a large commercial scale belongs to the species *Ostrea gigas*, Thunberg (fig. 1), which can be distinguished from other species of the genus *Ostrea* by its elongated and rather soft shell of subtriangular shape. The concave lower valve of this species has an elongated hinge and is provided with ribs, while the upper valve is flatter with a shorter hinge. The exterior of the shell is streaked with violet or purple. The interior is white; the muscular impression faint, colored violet, chestnut brown, or scarcely colored at all.

Some confusion exists regarding the taxonomy of Japanese oysters. Wakiya (1929) thinks that the species *Ostrea gigas* described by Thunberg in 1793 is identical with *O. laperousi* which Schrenk described in 1861, but believes that since the name *O. gigas* is preoccupied by a species described by Meuschen in 1781, the second name—that is, *O. laperousi*—ought to be used. Hirase (1930) distinguishes between long oysters (“nagagaki”), which he identifies as *O. gigas*, and short and round ones as belonging to the species *laperousi* (fig. 2). He

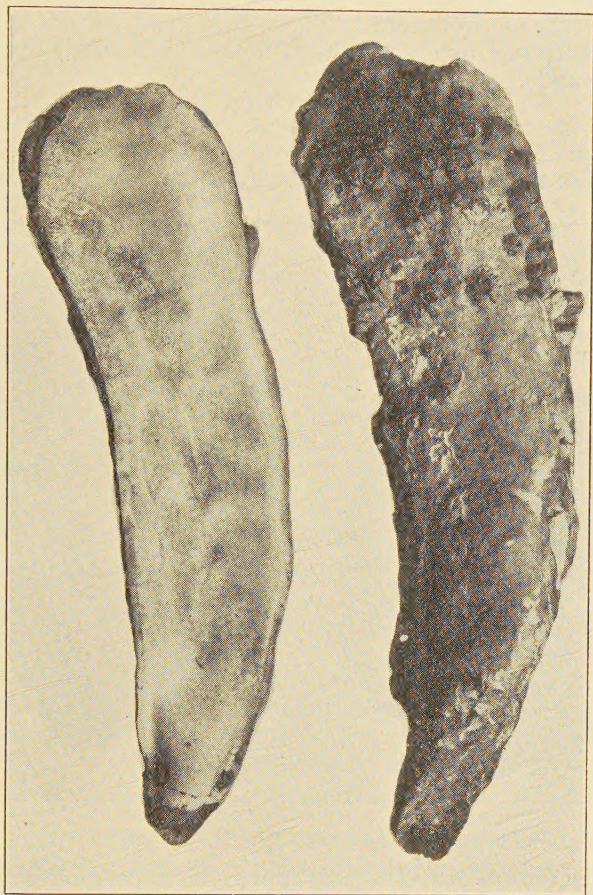


FIGURE 1.—Long Japanese oyster (“Nagagaki”) *Ostrea gigas* Thunberg

points out the existence of specimens intermediate between *gigas* and *laperousi*, which he thinks are hybrids. According to this author, true *gigas* are now rare in Japan, occurring only in the Tohoku and Hokkaido districts. Even in these places intermediate forms are predominant. The oyster which is widely distributed and cultivated for commercial purposes belongs, according to his view, to the species *O. laperousi*, Schrenk. Undoubtedly, the classification of Japanese oysters requires further investigation, but until it is completed we shall continue to use the name *O. gigas* as denoting the common Japanese oyster.

The mantle covering the soft body of the oyster is creamy or brownish with distinctly black edges. On account of the peculiar growth of the shell, the latter resembles a wedge which is very thick near the hinges tapering toward the distal end. The growth of the oyster is fairly rapid, especially during the first years of its life. In Japanese waters commercial oysters reach a marketable size of 4 or 5 inches in about two years. The largest specimen on record is 17.6 inches long and 3.8 inches wide (Wakiya, 1929). Similar to the American eastern oyster the shell of the Japanese species varies according to the environment. Those that grow on soft muddy bottoms or remain in clusters are much longer than single oysters living on hard grounds.

DISTRIBUTION

Ostrea gigas is widely distributed along several hundred miles of the coast line of Japan from the northernmost end of Hokkaido to

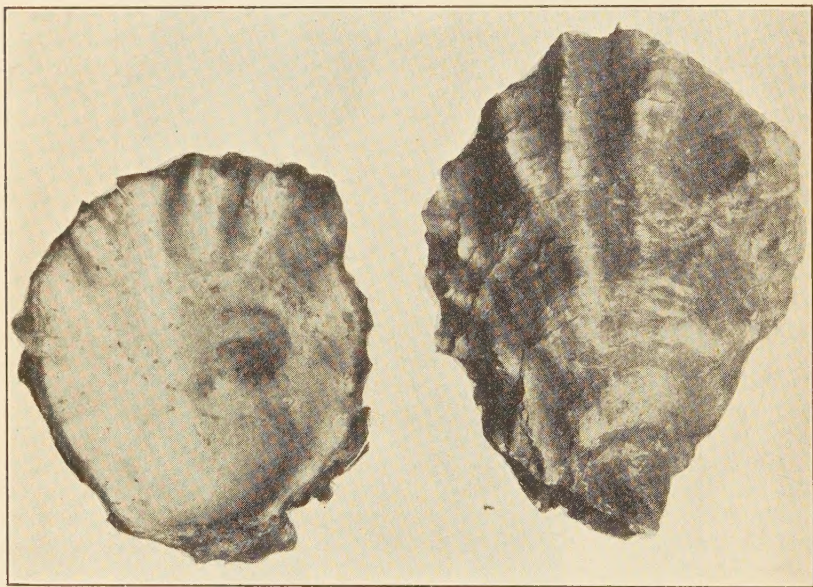


FIGURE 2.—Round Japanese oyster, *Ostrea laperousi* Schrenk

the southern end of Kiushiu, and along the corresponding continental coast of Asia. According to the Japanese investigators (Wakiya, 1929; Amemiya, 1928), it prefers estuaries with somewhat turbid water, and is rather indifferent to the character of the bottom, thriving equally well on mud, sand, or gravel. The species tolerates a wide range of salinity occurring in the waters in which the concentration of salts at high tide varies from 13 to 31 parts per thousand. According to Amemiya (1928) the optimum range of salinity for the development of this oyster is from 19 to 27 parts per thousand.

This oyster is a typical inhabitant of the intertidal zone, living in large numbers above the low-water mark. Wakiya (1929) states that the upper limit of its distribution corresponds to the level which

is exposed for seven hours during each tidal cycle; that is, one high and one low water. On natural oyster bottoms it is more abundant around low-water level, although its vertical distribution may extend in certain localities to a depth of several fathoms.

SETTING AND SPAWNING

The Japanese oyster is a dioecious organism—that is, its sexes are separate—although the sex ratio is not constant but varies greatly on different grounds. It has been shown by the experiments of Amemiya (1928a) that a considerable number of individuals kept under observation changed sex from female to male or from male to female. The Japanese investigator thinks that at the beginning of every spawning season the oyster develops into male or female independently of the sex of the same specimen during the preceding season; in other words, that the sex change, if it appears, occurs only once in a year. This interesting problem has not been completely studied, however, and requires further investigation.

In central Japan the spawning season extends from the middle of May until the end of June when, according to the Japanese authorities, the temperature of the water over oyster beds reaches 77° F. No Japanese records are available which show the relation between the temperature of the water and time of spawning. In 1929 the author performed a series of experiments on Japanese oysters grown in Samish Bay (Puget Sound). These oysters were brought as seed from Japan and grown in the northern section of Puget Sound where they never spawned, presumably on account of the low temperature of the water. Several dozen large ripe oysters were taken from this bay and shipped to Pacific Grove, Calif., where they were studied in the laboratory. It was found that exposure to a temperature of 86° F. provokes abundant shedding of eggs. Temperature is not the only factor which stimulates spawning in this species. Similar to conditions described by the author in the American oyster (Galtsoff, 1929–1932) spawning of *Ostrea gigas* can be induced by the addition of sperm. The results of experiments along this line show that the presence of sperm in the water stimulates the discharge of eggs by ripe females, provided the temperature of the water does not fall below 77° F. No positive results were obtained when the temperature of the water was below that mark, although the same females immediately responded to the addition of sperm when the water was warmed to 77° F. The results of these experiments seem to corroborate the ecological data given by the Japanese observers. It is, however, quite possible that there exist other stimulants which may provoke spawning of the oyster at temperatures lower than 77° F. It is hoped that further investigations will throw more light on the spawning habits of this species.

CULTIVATION

The cultivation of this mollusk began about 300 years ago and is carried on at present along the entire coast of Japan. Official statistical data published by the Japanese Ministry of Agriculture and Forestry (1930) show that 37.59 million kilograms (82.7 million pounds) of oysters were produced in 1929. Of this amount cultivated bottoms yielded 25.50 million kilograms (56.1 million pounds). The area of

oyster bottoms under cultivation is 24.79 million square meters, or 6,125.6 acres. Assuming that the figures of the report refer to the total weight of live oysters with their shells (the official report fails to state this fact) and that 1 bushel weighs about 70 pounds, the average productivity of Japanese oyster farms can be estimated as being equal to 1,308 bushels per acre. This high annual yield is undoubtedly attributable to the elaborate method of cultivation.

The Japanese method of oyster culture consists in the employment of various types of spat collectors set on tidal flats and arranged in lines and rows in such a manner as to insure the best exposure to the currents. The most common type of collector is made of light bamboo poles, although other plants, as for instance cherry trees, are used. In many localities instead of brush collectors oyster shells are scattered over the bottom. With the increased demand for clean seed for importation into the United States the Japanese producers have developed a new "hanging" method of catching spat; it consists of suspending threaded oyster, scallop or abalone shells from wires running between posts set in the mud. The advantage of this method is that shells never touch the bottom and are protected from the attacks of drills and other pests. Successful attempts were made also in using tarred rope wound around wooden frames and suspended from the floats.

Data concerning the nutritive value of the Japanese oyster are fragmentary. The only reference the author was able to find appears in a Japanese pamphlet *Talks on Oysters* issued by the Kokusai Yorei Kabushiki Kaisha (International Oyster Breeding Co., Tokyo, 1931).² According to this publication the "best" and "ordinary" market oysters have the following composition (the figures are percentages referring to dry weight of meat):

	Protein	Fat	Carbo- hydrate	Inorganic matter
Best oysters.....	42.7	8.9	38.0	8.3
Ordinary oysters.....	44.9	7.1	25.2	22.8

The glycogen content, according to the same source, varies with the season from 1.25 per cent (of wet weight) in September to 5.20 in December, and 4.60 in January. Data for the period February–August are wanting.

The mineral contents of the meat of Japanese oysters from Puget Sound were studied by E. J. Coulson (unpublished report) of the United States Bureau of Fisheries (Table 1).

TABLE 1.—*Mineral content of oysters from Puget Sound*

[Milligram per kilogram fresh basis]

	Dry matter	Iron	Copper	Manganese
	<i>Per cent</i>			
<i>O. lurida</i> , Oyster Bay.....	18.81	40.3	13.4	3.65
<i>O. lurida</i> , Mud Bay.....	17.07	39.1	12.3	3.47
<i>O. gigas</i> , Mud Bay.....	22.42	75.3	6.5	7.60
<i>O. gigas</i> , Samish Bay.....	17.90	60.1	4.5	5.03

² The author desires to express his thanks to V. N. Ayvazoglou of the Bureau of Mines, Department of Commerce, for the translation of the Japanese text.

Previous investigations by the bureau (unpublished report) have shown that the mineral content of eastern American oysters varies widely according to the locality. It is impossible, therefore, from a small number of observations to draw any conclusion as to the comparative nutritive value of the three species of oysters.

IMPORTATION OF THE JAPANESE OYSTER INTO THE UNITED STATES

The idea of importing oysters from Japan for cultivation in the waters of the Pacific coast originated in 1899 when this question was taken up by the State fish commissioner of the State of Washington with Professor Mitsukari of the Imperial University of Tokyo, who suggested that oysters from the beds at Akkeshi Hokkaido, the northern island would be best adapted for transportation to America. In 1902 and 1903, 4 and 12 carloads, respectively, of Japanese oysters were shipped from Japan and were planted in Puget Sound. Another attempt was made in 1905 by a group of Japanese who acquired an area of oyster lands in Samish Bay near Bellingham. Although their efforts were successful and the oysters grew well, the practice continued on a small scale until after 1922 when Samish Bay oyster grounds were acquired by a new company which began to import from 1,500 to 4,000 boxes of seed annually. Table 2, based on statistics gathered by the United States Bureau of Fisheries, shows that the production of Japanese oysters in the State of Washington slowly increased from 1923 to 1929. No figures are given for the years of 1927 and 1928 because the production of Japanese and eastern oysters for these years was entered together under eastern. A sudden increase in 1930 was due to the activities of several new oyster companies organized in 1928-29, which acquired large tracts of oyster bottoms in Willapa Bay and in Puget Sound, and imported considerable quantities of Japanese seed. It has been estimated that at least 17,000 boxes of seed oysters were planted in 1930 and 15,000 boxes in 1931. According to the statement published by the Willapoint Oyster Growers Association (1931), an organization operating during the last two years in Willapa Bay, imported seed oysters were brought in boxes of 2 cubic feet capacity holding about 800 oyster shells punched in the middle and strung on wires. Attached to each shell were from 4 to 30 small seed oysters. A box of seed contained from 5,000 to 20,000 small oysters. Immediately upon arrival at Seattle the oysters were transported to South Bend by freight, loaded on a flat bottomed boat and planted in Willapa Bay. The cost of oyster seed delivered at Seattle was about \$5.25 per box and an additional 50 cents covered the expense of handling and planting.

TABLE 2.—*Production of oysters in the State of Washington*

[In thousands of pounds of meat]

	1922	1923	1924	1925	1926	1927	1928	1929	1930	1931
Eastern.....	45	45	36	10	20	113	74	9	2	-----
Native.....	555	682	651	663	698	616	615	609	303	-----
Japanese.....	35	10	16	28	60	-----	-----	66	228	400

Taking the smallest figure of 5,000 seed per box, the total number of seed oysters brought during the 2-year period can be estimated as being equal to 150,000,000 oysters. Of course, it is difficult without making a special study to determine the percentage of oysters that have reached maturity, but it is claimed that losses from time of planting of the seed to the time of marketing are extremely small. The company operating in Willapa Bay made a test planting of a box full of oyster seed which were scattered apart from the general planting; 18 months later it was found that this seed had grown into 9,998 adult oysters. Assuming that this observation is correct and that 250 oysters make up a bushel we may conclude that 1.6 bushels of seed (2 cubic feet) yielded in 18 months 40 bushels of marketable oysters. Should this figure be applicable to Willapa Bay in general, seed planted in 1930 and 1931 must have yielded over 600,000 bushels of market oysters.

The exact data on the number of Japanese oysters marketed in 1931 are not available, but it has been estimated by one of the leading oyster companies of the State of Washington that at least 50,000 gallons (350,000 pounds) of meat were marketed in that year under the name "Pacific oyster," the brand which was agreed upon by the oyster growers of the State. This represents probably not more than one-seventh of the marketable oysters left on the bottoms because of the lack of demand. It is reasonable to expect that at least 300,000 gallons (2,100,000 pounds) will be produced from the oysters imported in 1930-31. This estimate does not take into consideration any increase in number of oysters due to natural propagation.

According to the latest information received by the United States Bureau of Fisheries about 30,000 boxes of Japanese seed will be delivered during the spring of 1932. Of this amount 20,000 will be planted in Padilla Bay (northern end of Puget Sound), 6,000 in Willapa Bay, 500 in Grays Harbor, and 3,500 in other places of Puget Sound. It is interesting that the Japanese seed producers have improved the quality of the seed to such an extent that some of them guarantee the survival until maturity of 20,000 oysters per box. If this expectation is justified the seed oysters imported in 1932 should produce in about two years 15.9 million pounds of oyster meat or nearly 15 per cent of the total production of market oysters in the United States in 1930.

PROPAGATION OF JAPANESE OYSTER IN THE STATE OF WASHINGTON

The question whether the Japanese oyster can be propagated in the United States on a large commercial scale has not been solved. It is certain that during the last two summers (1930 and 1931) there has been a light set of Japanese oysters in Willapa Bay, at the mouth of Nazel River, around Long Island and near Nahcotta, although according to the report of Dr. A. E. Hopkins this set is only scattered and of no commercial importance. The unsatisfactory results are probably due to the fact that, on account of muddy water, cultch planted in these bays becomes silted over quickly. Doctor Hopkins believes that a much greater set would be obtained if cultch were put into the water at the right time; that is, a few days before setting. Local observers state that the Japanese oyster spawns late in the

summer after the native and eastern oysters have already discharged their sexual products. In 1932 some of the Japanese oysters in Willapa Bay contained spawn even in midwinter, at the coldest time of the year (March). At present the oyster planters in Willapa Bay consider that buying seed is much cheaper than catching them locally and make no attempt to become independent of Japan.

EFFECT OF IMPORTATION OF JAPANESE SEED ON CULTIVATION OF OLYMPIA OYSTER

There is no doubt that the importation of large numbers of Japanese oysters must have a pronounced effect both on the highly specialized cultivation of the native west coast species and on the oyster industry in general. First, the planting of millions of small oysters brought from a foreign country is bound to produce profound biological changes in the oyster growing bottoms; second, an overproduction of a cheap and new to the customer product, which is

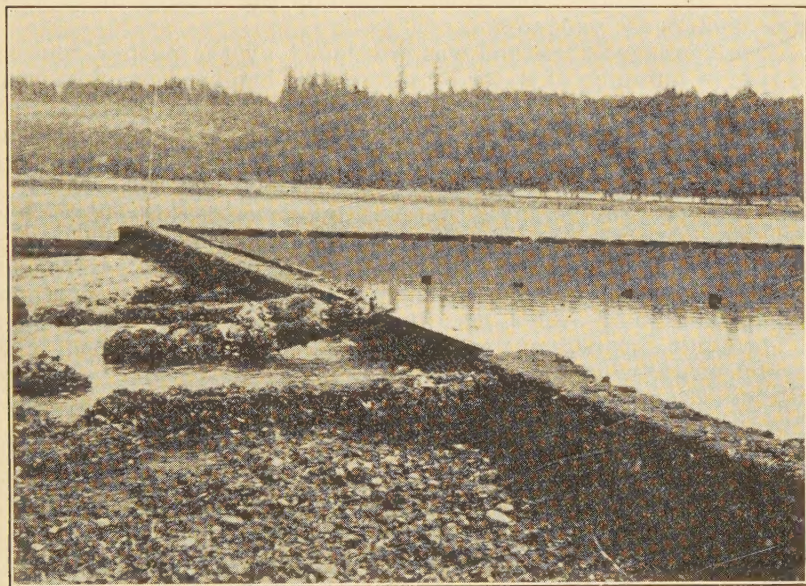


FIGURE 3.—Oyster farm in Puget Sound, Wash. Cement dikes, exposed at low water, are used for cultivation of native Olympia oysters

offered in competition with the old one, disorganizes the market and reflects unfavorably on the existing prices. A large and sudden decrease in production of native oysters from 601,000 pounds of meat in 1929 to only 303,000 pounds in 1930 (see Table 2) is due probably to this cause. Laying aside the economic phase of the problem, we shall devote our further discussion to the biological side of it and shall attempt to analyze the possible effect of the introduction of foreign oysters on native species.

Suppose that an oyster farmer has several diked bottoms (fig. 3) on which he cultivates the native Pacific coast oyster, *Ostrea lurida*; he later decides to introduce the Japanese oyster and scatters several hundred bushels of that seed among the natives. Within two years

the Japanese oyster is over 5 inches long and, of course, occupies a much larger area of bottom than does the small native oyster. The measurements of the specimens collected by the author from one oyster bed in the State of Washington show that no more than three adult *Olympia* oysters can be placed on the area occupied by one Japanese oyster.

All the oysters in spite of their differences in shape, flavor, and other qualities have similar habits and their modes of living are nearly alike. They all feed by straining the water through their gills and ingesting the microscopic plants suspended in the water. The more water they filter the more food they obtain, and the better they grow. Oysters grown on crowded bottoms or in clusters are small and slender because living in close proximity to each other they have to filter the water that has already been strained by their neighbors and deprived of food. Those which occupy a more favorable position on the periphery of the cluster, or those which possess a more powerful pumping mechanism feed and grow better than their less fortunate competitors. Similar conditions prevail on the bottom upon which single oysters are scattered.

A few years ago a method was developed by the author whereby the rate of pumping of water by the oysters can be accurately measured. The readers interested in a description of it are referred to the publication by Galtsoff (1928), in which all the details of the method and its application are given. Measurements made in 1929 on Japanese oysters grown in Samish Bay show that at a temperature of about 60° F. adult Japanese oysters filter water at the rate of about 2,000 cubic centimeters (slightly over 2 quarts) per hour, whereas at the same temperature the rate of filtration of water by the native *Ostrea lurida* is 300 cubic centimeters (about 10 ounces) per hour. Hence, three small oysters occupying the area equal to that covered by one adult Japanese oyster would consume less than one-half of the amount of water used by the latter. Should the bottom be covered with mixed populations of two species, the native oyster would suffer from the competition with larger and stronger Japanese species.

The struggle for existence will be even more pronounced in the propagation of the two species. Assuming that conditions on the bed where both species of oysters are grown are equally favorable for their spawning and setting, the degree of success in propagation of either species would be determined by their relative fecundity. It has been observed that Japanese oysters develop very large quantities of sexual products. According to the author's observations made in October, 1929, one Japanese oyster discharged in three spawnings 92,000,000 eggs (Galtsoff, 1930a). This was apparently but a small fraction of the total number of eggs developed in this specimen, the reproductive tissue of which, examined immediately after spawning, was thick and contained a large number of eggs. In another experiment five oysters kept together discharged 278,800,000 eggs. Although in this experiment the average number of eggs per oyster was only 55,800,000, it has been noticed that one specimen contributed the greatest portion of the total number of eggs spawned. These figures illustrate the enormous fecundity of Japanese oysters.

During spawning the eggs are discharged into the water and are inseminated outside the organism. There is no doubt that a large percentage of them perish before they even develop into free swim-

ming larvæ. The life of the latter is full of danger, and those which successfully accomplish their development and permanently attach themselves to some suitable object have to pass through many vicissitudes. A great many perish before completing their larval development, being carried away by the tides, becoming a prey of fishes and other marine organisms subsisting upon the small creatures of the sea, or being lost in the mud before they find a suitable place of attachment. It is impossible to estimate what percentage of eggs discharged by the female reaches maturity, but there is no doubt that large numbers of them perish. On the other hand, the greater the number of eggs shed the greater will be the number of larvæ to accomplish development. It is evident that, of two species of oysters living together and spawning at the same time, the one which produces the greater number of eggs has a better chance of establishing itself, and in the course of time the more prolific species will replace its less prolific competitor. It is of interest, therefore, to have some idea of the fecundity of the native *Olympia* oyster.

The insemination of eggs of this oyster takes place inside the organism and the larvæ are held for some time, possibly two weeks, in the mantle chamber of the parent. Apparently an oyster may bear several broods each season. It has been estimated by Dr. A. E. Hopkins (unpublished report) that the number of larvæ in a brood is roughly proportional to the size of the parent and varies from 70,000 in the smallest to 355,000 in the largest. The average number per oyster was 170,000. One must bear in mind that when released into the water the larvæ of the *Olympia* oyster have already developed a shell and, therefore, are better protected than the larvæ of the Japanese or eastern American oysters, which develop outside the parent and are more exposed to danger. There is no doubt, however, that a certain percentage of *Olympia* larvæ perish before they attach themselves to cultch. Let us compare now the maximum number of oyster larvæ comprising the brood of *Olympia* oysters with the number of eggs spawned by the female *Ostrea gigas*. Remembering that 3 *Olympia* oysters occupy the place needed for 1 Japanese oyster, and assuming that both species have equal sex ratios, we conclude that while 3 native oysters produce about 1,000,000 larvæ (maximum figure), 1 Japanese female may discharge nearly a hundred million eggs. Although a great number of them will die, there is but little doubt that under conditions suitable for the propagation of the species the Japanese oyster in a short time will outnumber the less fecund native oyster. This conclusion is corroborated by the observations recently made by Hopkins in Oyster Bay and Little Skookum, Wash., where already one may find native Japanese oysters scattered about both in the dikes and on the gravel of the beaches, even though few spawners were ever planted in the vicinity.

STRUGGLE FOR EXISTENCE BETWEEN THE NORTH EUROPEAN (*O. EDULIS*) AND PORTUGUESE OYSTER (*O. ANGULATA*)

So far we have discussed a more or less theoretical case, because up to the present time large plantings of Japanese seed have been made only in the localities where beds of native oysters had been badly depleted. In other cases observed by the author only a small number of Japanese oysters were planted in the dikes together with

the native oysters, or the Japanese oysters were kept in the water in which they fail to spawn (Samish Bay).

It is interesting to find out whether the struggle for existence between the two related species has ever been observed in nature. The past history and the present fate of the European oyster throws light on this problem. The European oyster, *Ostrea edulis* L., has been cultivated since ancient times. Historical records show that about 2,000 years ago the Romans employed oyster-cultural methods similar to those which at present are still in use in Italy. At the beginning of the nineteenth century extensive natural beds existed along certain sections of the French and British coasts. Upon the cessation of the Napoleonic wars oyster dredging, which was discontinued during the previous decade, began with great energy and reached a peak probably in 1843, when 70,000,000 oysters were marketed. By the middle of the century the natural beds in France were nearly depleted and the supply decreased with great rapidity. The reestablishment of this important fishery began in 1855, when DeCoste made the first attempts at introducing old Roman methods of cultivation and tried to apply them to local conditions. Although the immediate results were disappointing and the brilliant plan of converting the entire coast of France into a great oyster garden was an obvious failure, fundamentally DeCoste's ideas were correct. After a period of disillusionment they were gradually accepted and formed the basis for the rehabilitation of the French oyster industry.

The life history of the European oyster is similar to that of the Pacific coast oyster. Both species are hermaphroditic; in both of them the eggs are fertilized in the body of the parent and are held there for some time before the larvæ are released into the water. Although the European oyster is larger than the Pacific species, it is much smaller than our eastern oyster. Besides *O. edulis* there exists in Europe another species of commercial oyster, *Ostrea (Gryphaea) angulata* Lamarck, or Portuguese oyster, introduced as a substitute for the more delicate *O. edulis*. In general appearance it differs from the round and flat shell of *O. edulis* by its long, irregular, and heavy shell. One valve, deeply trenchlike, contains the entire animal. The meat of the oyster, slaty or bluish in color, is outlined by the broad, jet black margin of its mantle. The sexes are separate. The Portuguese oyster is found growing in clusters along the shores in shallow water or between the tide marks. With regard to conditions of living, sex, and structure of shell, it resembles the American oyster. On account of its tough meat and flavor it is not so highly esteemed as are the rounded and flat northern oysters of Europe.

Until the middle of the nineteenth century this species, confined to the Mediterranean where it was very abundant, was not found in the Atlantic. Its appearance on the western coast of France dates back probably to 1856 when for the first time it was noticed near Verdon. Since that time its number has been gradually increasing while the native European oyster shows a steady decline. In 1870, *O. edulis* entirely disappeared in certain sections of the coast and was fully replaced there by the Portuguese species. The invasion of the Portuguese species continues and causes considerable alarm to those engaged in the industry and conservation of the native French oyster. The following figures of production for the 5-year period, 1925-1929, taken from the official publication of the French Gov-

ernment, illustrate this point very clearly. Whereas the production of native oysters in 1929 was approximately one-fourth of the amount produced in 1925, the production of Portuguese oysters for the same period of time more than trebled.

TABLE 3.—*Oyster production in France*

[In thousands of specimens]

	1925	1926	1927	1928	1929
French oyster.....	2,361	3,249	843	524	668
Portuguese oyster.....	300,702	269,865	561,659	925,703	914,404

The causes of the replacement of a native species by a foreign invader were studied by French biologists. In 1892 Viallane showed that a Portuguese oyster filters 5.5 times more water than does the French oyster of the same age. From this observation the conclusion was drawn that when the two species live together the Portuguese oyster deprives the native from its share of nourishment, forcing it to exist on a diminished ration. It has been recommended that no Portuguese oysters be planted in the "parcs" where native oysters can live.

The situation is, however, more complex than it appears to be. The crowding out of a native species by a newcomer is not only due to a relatively higher efficiency of feeding but is primarily dependent on its rate of propagation. Danton (1914) noticed that the setting of Portuguese seed on collectors in Arcachon is so dense that no space is left for the attachment of the native larvæ. Moreover, on account of the higher rate of feeding the Portuguese oyster grows faster than the native and smothers those few native spat that may have attached to the collectors. French investigators (Danton, 1914, and Ranson, 1926) agree that the introduction of Portuguese oysters into a new territory in which the northern species is being cultivated would result in the crowding of the collectors by the Portuguese spat. Naturally this interferes with the propagation of the native oyster, which in a few years will be completely driven out by its competitor. The struggle for existence between the two European species and the apparent victory of the Portuguese oyster over its northern relative gives one an insight into what may happen should large quantities of Japanese oysters be introduced to the Atlantic coast of America.

On account of high temperature and wide range of salinity the waters of the Middle Atlantic and Southern States appear to be suitable for the propagation of the Japanese oyster. The enormous fertility of this species coupled with its high rate of growth and general hardiness would be of great advantage in the struggle with the native eastern species, which probably in the course of time would be nearly replaced by the invader. It is very doubtful that the industry would gain by this substitution.

Experiments performed by the author in July, 1932, show that cross-fertilization easily occurs between *Ostrea virginica* and *O. gigas* resulting in the development of apparently normal larvæ. It is not known, however, whether the hybrids possess any better combination of characters than their parents.

INTRODUCTION OF ENEMIES

So far we have dealt with the probable effects of a foreign oyster on the life of a native species. It is, however, impossible to bring in quantities of seed or adult oysters without bringing a number of other organisms growing on their shells. We know that various dangerous pests were introduced with oysters shipped from the Atlantic to the Pacific coast and to Europe. One of the most dreadful enemies of the oysters is the so-called oyster drill, *Urosalpinx cinereus* Verrill, a small snail which preys on oysters by boring through the shell and sucking the meat. Millions of young and adult oysters are destroyed annually by this organism, the control of which is very expensive and inefficient. Oyster drills brought to the Pacific coast with the eastern oysters became very common in Puget Sound and other bays and estuaries in the States of Washington and California. With the shipment of American oysters, it has been introduced in England where it devastated large areas of oyster bottoms in the British Isles. Like many other marine snails the drill lays its eggs in capsules attached to the oyster shells, and, therefore, easily withstands transportation and exposure to air.

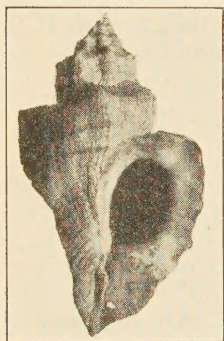


FIGURE 4.—The Japanese drill, *Tritonalia japonica* Dunker

The Japanese drill, *Tritonalia japonica* Dunker (fig. 4) has been brought in from Japan and established itself in several bays of Puget Sound. This mollusk is much larger than the American drill and is very destructive to native oysters. The slipper shell, *Crepidula fornicata* L., is an innocent mollusk very common in the shallow water of the Atlantic coast. It has been introduced to the Pacific coast and in Europe where it propagates very prolifically, attaching itself to oysters. Although not a direct enemy of the oyster, it has become a serious nuisance, overloading the oysters and stunting their growth.

The boring sponge, *Cliona*, honeycombs the shells of the oyster, weakening or even completely destroying it. In many localities the attacks of this sponge constitute a serious menace to oyster culture. This and other probably more destructive species of sponge can easily be introduced with foreign seed. A Japanese biologist Hirase (1930) states: "No papers have yet been published in Japan on the enemy of *Ostrea*, though certain animals such as *Porifera*, *Echinodermata*, *Mollusca* (*Thais* and *Rapana* only), *Arthropoda*, and some lower plants are vaguely regarded as enemies."

The oyster shell is an abode for many worms which live on or between its valves. Some of them are very destructive. Extensive oyster beds in Georges River, Australia, were virtually exterminated in 1886-87 by a so-called worm disease. The term applies to the deposition of mud between the valves of the oyster causing its death. The mud is carried into the oyster by the mud worm, *Polydora ciliata*, which finds its way into the shell of nearly every oyster and accumulates mud over which the oyster deposits a very thin shell. In Australia the worm mud is regarded as a serious pest, the control of which is accomplished by growing oysters on slabs or stacks above the bottom. The introduction of this animal into our waters would have been disastrous to the American industry.

Besides large animals and their eggs which could be detected by careful examination, oyster shells contain a large number of microscopic organisms. The propagation of some of them may become so intensive that the organism, which is more or less innocent in its natural habitat where its growth and reproduction are checked by its natural enemies, may become destructive in a new environment. The possibility of this danger should not be overlooked.

The examples just mentioned suffice to show that great care must be exercised in the experiments on acclimatization of foreign species. Before attempting to introduce any of them, due consideration should be given to their qualities, life histories, parasites, and possible effects of their introduction on native fauna. Should the foreign species present obvious advantages over native organisms, as for instance better nutritive value, its introduction could be justified. If the advantages are dubious there seems to be no reason for importing organisms of uncertain qualities and taking chances of bringing in pests that may cause destruction to the native fishery. There is at present no Federal law which forbids or restricts the importation of living marine animals and plants. The policy of development and administration of shellfish resources is entirely within the jurisdiction of different States which have to determine for themselves whether the introduction of foreign mollusks is desirable. In the case of the Japanese oyster it is the author's opinion that its introduction to the Atlantic coast will unfavorably affect the oyster industry.

It is true that the rapid growth of this mollusk, which even in the cold waters of Puget Sound reaches marketable size in less than two years, made it possible for the planters to obtain good returns on their investments. Yet the same ability may under certain conditions be considered a handicap rather than an advantage because the unmarketable oysters left on the ground will grow beyond the marketable size and become too large for trade.

Should the Japanese oysters fail to spawn, as it happens in many localities of the Pacific coast, the presence of a large amount of gonad material in their bodies would unfavorably affect the quality of the meat. Such oysters do not stand shipping and sometimes develop a bitter taste.

The economic problem of the control of the production in relation to the capacity of the market should not be overlooked. There are already indications of the overproduction of Japanese oysters in the State of Washington which causes considerable decrease in prices of shucked oysters. It is doubtful that at present low prices (March-April, 1932) the importers of seed can make profitable returns on their investments. Further increase in the import of the Japanese seed and its expansion to the Atlantic coast will only aggravate both the local situation and the whole oyster industry of the country.

On the other hand, by applying modern methods of spat collection and transplantation the cultivation of our eastern oyster in its natural habitat can be much better controlled than the propagation of a foreign species. On account of their slower rate of growth adult eastern oysters can safely be left on grounds and sold when there is demand for them. At the beginning of the oyster season, in the fall, most of them have completely discharged their spawn and accumulated sufficient amount of glycogen, which makes them "fat" and constitutes one of the most valuable components of the oyster meat.

Present market conditions and keen competition among the oyster-producing States call for a production of oysters of highest quality. Success seems to be assured to those who can standardize the quality of their product and guarantee a continuous supply. This can be achieved by the use of improved methods of cultivation and by the growing and marketing of oysters of highest quality rather than by experimenting with foreign species.

BIBLIOGRAPHY

AMEMIYA, IKUSAKU.

1928. Ecological studies of Japanese oysters, with special reference to the salinity of their habitats. Journal, College of Agriculture, Imperial University of Tokyo, Vol. IX, No. 5, May 15, 1928, pp. 332-382, Plates XVI-XX, 3 figs. Tokyo.

1928a. A preliminary note of the sexuality of a dioecious oyster, *Ostrea gigas* Thunberg. Japanese Journal of Zoology, Vol. II, No. 1, December 31, 1928, pp. 99-102. Tokyo.

DANTON.

1914. L'Huître Portugaise tend-elle à remplacer l'*Ostrea edulis*. Comptes-Rendus de l'Académie des Sciences, 1914, vol. 158, pp. 360-362. Paris.

GALTISOFF, PAUL S.

1928. Experimental study of the function of the oyster gills and its bearing on the problems of oyster culture and sanitary control of the oyster industry. Bulletin, Bureau of Fisheries, Vol. XLIV, 1928 (1929), pp. 1-39, 13 figs. Washington.

1929. Oyster industry of the Pacific coast of the United States. Appendix VIII, Report, Commissioner of Fisheries, 1929 (1930), pp. 367-400, 13 figs. Washington.

1930. The rôle of chemical stimulation in the spawning reactions of *Ostrea virginica* and *Ostrea gigas*. Proceedings, National Academy of Sciences, vol. 16, No. 9, September, 1930, 1 fig. Washington.

1930a. The fecundity of the oyster. Science, Vol. LXXII, No. 1856, July 25, 1930, pp. 97-98. New York.

1932. Spawning reactions of three species of oysters. Journal, Washington Academy of Sciences, Vol. XXII, No. 3, February 4, 1932, pp. 65-69. Baltimore.

HIRASE, SHINTARO.

1930. On the classification of Japanese oysters. Japanese Journal of Zoology, Vol. III, No. 1, March 30, 1930, pp. 1-65. Tokyo.

KOKUSAI YOREI KABUSHIKI KAISHA (INTERNATIONAL OYSTER-BREEDING COMPANY).

1931. Kaki no hanasi (Talks on oysters). 1931. In Japanese.

MINISTÈRE DE LA MARINE MARCHANDE.

1931. Statistique des Pêches maritimes. 1929, 176 pp. Paris.

MINISTRY OF AGRICULTURE AND FORESTRY, JAPAN.

1930. The statistical abstract of the Ministry of Agriculture and Forestry. 1929, 255 pp. Tokyo.

RANSON, GILBERT.

1926. L'Huître Portugaise tend-elle à remplacer l'Huître Française? Office Scientifique et technique des Pêches Maritimes, Notes et Memoires No. 47, 1926, pp. 2-9.

VIALLANES, H.

1892. Recherches sur la filtration de l'eau par les Mollusques et applications à l'Ostréiculture et à l'Océanographie. Comptes Rendus Hebdomadaires des Séances de l'Académie des Sciences, vol. 114, pp. 1386-1388. Paris.

WAKIYA, Y.

1929. Japanese food oysters. Japanese Journal of Zoology, Transactions and Abstracts, vol. 2, No. 3, August 20, 1928, Plates VIII-X. Tokyo.

WILLAPAPOINT OYSTER GROWERS ASSOCIATION.

1931. Oyster farming for profit at Willapa Bay. A report of progress in shellfish culture, 34 pp. Seattle.